Interest of OQAS
(Optical Quality Analysis System in cataract surgery).

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The OQAS (Optical Quality Analysis System) is an innovating instrument which provides essential information concerning visual function to clinicians. It allows measuring of the joint effect of high degree optical aberrations and loss of transparency of ocular tissues on the quality of the retinal image. From the analysis of an image of a light spot focused onto the retina and collected in the retinal plan this promising investigation technique which has been evaluated at the Rothschild Foundation for more than a year offers the possibility to objectivise the effect of the loss of transparency of the ocular environments. This article is dedicated to the description of the principles used by the OQAS technology and provides to the clinician a statement of the optical quality of the human eye.

Introduction

Vision is the capacity to perceive light, colours, and shapes. Our most valuable sense is a complex phenomenon which uses a cascade of events starting with the capture of photons coming from an observed target, and then continuing with a visual feeling coming from the activation of specialized neuronal structures of the occipital cortex.

This process' first step can be described as optical, because it includes successive refractions through the optical interfaces of the eye (lachrymal film, cornea, crystalline lens, vitreous) of light waves all the way to the photo receptors of the retina. This major step has an impact on the quality of the retinal image: it should take place under good conditions in order to provide a good vision.

The second step, known as „sensory“, begins after reception of the information by the retinal photoreceptors; it includes the coding and the transfer of this information towards the specialized cerebral cortex, and is completed by a visual feeling. Vision quality results from the execution of these two stages. Even if the knowledge of the achieved modulation by the neuro-cognitive system remains necessary for the prediction of vision quality, the retinal image's quality allows the clinician to check the good process of the optical step of the vision. The two major causes of the reduction of the optical quality of the human eye observed in clinical practice are the presence of uncorrected optical aberrations (refractive anomalies), and the partial reduction of ocular transparency whose corollary is the existence of an increased light scatter[1]. The main sources of physiological and pathological ocular scatter are reported in **Figure 1**.

Sources of physiological ocular Scatter

Cornea
Reduced scatter dependent on the diameter of collagenous fibres and their regular spacing

Crystalline lens
Thicker than the cornea
Comprise concentric cellular structures
Induced more diffusion than the cornea.

Vitreous and aqueous humor
Little scattering

Increase in the ocular diffusion:

Cornea
Corneal refractive surgery, haze, dystrophies, slips...

Crystalline lens
Primitive cataract, in particular in its cortical form, secondary cataract

Vitreous and aqueous humor
Hyalites, tyndall, flare

figure 1

The aberrometers which were introduced since the beginning of the years 2000 allow a measurement of low and high degree of the optical aberrations but not of the loss of ocular transparency[2]. So the estimated optical quality provided by an aberrometer is only valuable if the transparency of the eye does not significantly decrease.

The OQAS (Optical Quality Analysis System) is the only apparatus currently available which provides a direct measurement of the combined effect of the optical aberrations and the loss of ocular transparency on the optical quality of the eye. The data provided by this instrument are established by a study of the retinal image obtained after focusing an infra-red light. This light beam can be projected according to various vergence in order to carry out a group of measurements corresponding to the image of a spot located at various distances. This analysis enables to estimate the importance of ocular scattering (reduction of the ocular transparency), and to predict its effects on the contrast sensitivity and the maximum theoretical visual acuity. The Dynamic measurements enable to assess the accommodation's quality and/or the field depth.

Principles of the analysis of ocular optical quality with OQAS

The reliability of any optical imagery instrument is correlated with the way in which this instrument can turn a light source spot into the most accurate image possible. OQAS enables the retinal projection of a source spot, and to analyze its characteristics. OQAS' measurements derive all from the analysis of the retinal image of a spot. In simple words, the study of the quality of the ocular stigmatism provides the overall data's. The dimensions and the space distribution of light energy onto the retina after focusing on a source point through the ocular dioptres determine the aspect of the Spreading Function of the retinal spot (FEP). The acronym PSF (for the Anglo-Saxon equivalent „Point Spread Function") is commonly used in optics and will be mentioned in this article. The PSF can be represented as a two or three dimensional diagram, whose diameter conditions the separating power of the eye and its contrasts sensitivity. The maximum visual acuity is reached when the diameter of the point does not exceed the one of a foveal photoreceptor. It decreases of about its half when the diameter is multiplied by two, etc...

OQAS provides a tri dimensional representation of the retinal PSF under the aspect of a light intensity „peak" from an image collected by the CCD and translated into levels of grey. This allows an easier interpretation and comparison of the PSF. In the case of a transparent and deprived of optical aberrations eye (or when perfectly corrected), the focal image formed on the retina is not a point but a luminous spot whose diameter depends on that of the iridal pupil (pupillary diffraction). Diffraction is an essential limitation of absolute stigmatism; it necessarily requires a „widening" of the image dimensions which are formed according to the source point. The high degree optical aberrations (coma, spherical aberration, etc...) are noxious for the eye optical quality because they induce a reduction of the stigmatism which is added to the one imposed by the diffraction (**Figure 1A**). At last, the existence of a disorder of the environments results in a light scatter entailed by total or partial micro opacities then inducing a random pace dispersion of the light waves. The distribution of the light intensity is focused by the ocular dioptres and is definitely less compact (**Figure 1B**).

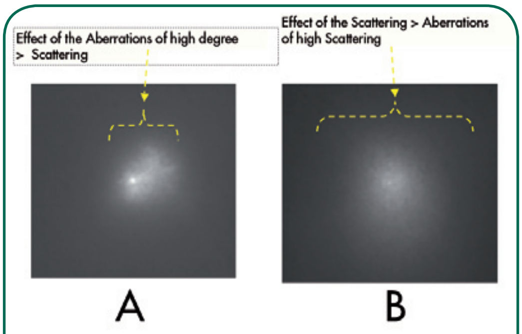

figure 1b

OQAS optical quality indices

One can predict the aspect of a more complex image from gathering the image formed from a light-source spot on the retina, as well as the retinal contrast reduction percentage. The main indices provided by the software's instrument are (**Figures 2 and 3**):

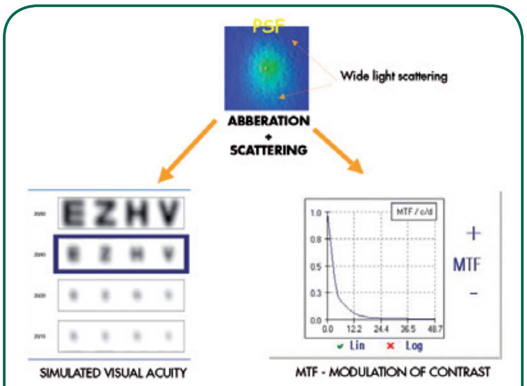

figure 2

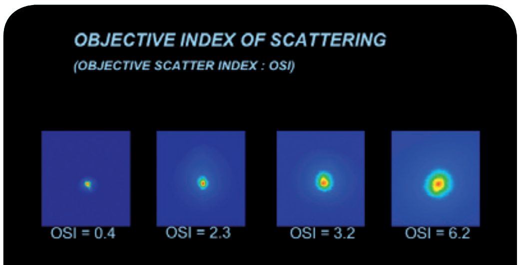

figure 3

- The maximum visual acuity predicted for objects with 100%, 50% 20% and 9% of contrast.
- This visual acuity is calculated by taking into account the optical characteristics of

the analyzed eye: aberrations, and ocular scatter.

• The MTF curve (Modulation Transfer Function): this curve represents the attenuation percentage of the contrast of the retinal image at various resolutions (space frequencies), and also includes the combined effects of scatter and high degree optical aberrations.

• A scattering index: this index is useful to quantify the scattering degree caused by the loss of transparency of one or more of the ocular structures, such as the haze and corneal opacities, cataract, hyalite...

In order to not be disturbed by sphero-cylindrical aberrations (second degree aberrations which can be corrected with glasses), the analysis of the retinal PSF must be carried out for the best sphero-cylindrical correction. The apparatus carries out a scrambling thanks to an integrated autorefractometer, a compensation of the spherical focus is performed, in order to combine the retina with a point located at a definite distance (the „infinite one" by defect). The "far vision" is also studied by combining the retina with a point located at the „infinite". Several images of the retinal focusing spots are collected thanks to a CCD sensor. The natural pupil diameter is measured by the instrument, but the measurements are taken with a fixed pupillary diameter chosen by the operator (from 3 to 6 mm). It is possible to estimate the depth of field of the studied eye by collecting series of measurements for points located at successive distances.

Measure sequence with OQAS

The instrument which occupies a similar volume as the one of an auto refractometer is equipped with a chinrest, a frontal v and is handled with a joystick. It is controlled by data-processing software. In addition to patient's standard data's (identity, date of birth, etc...), the user enters the refractive error's value (spherical equivalent) and chooses a given pupillary diameter for the analysis. It can be useful with patients presenting with a strong ocular astigmatism, to compensate with a cylindrical glass prior to the measurements. The diameter of the ocular pupil is measured once it is aligned on the light reticules, measured, and an automatic scrambling/unscrambling is performed by the instrument. The patient then stares at a test card representing a landscape. Once the focusing on the retinal-foveal plan is done, several captures of the retinal PSF are performed and then moderated. The accommodation exploration is carried out by performing repeated PSF measurements for the plans located on increasing vergence, which optically simulates the nearing of the plan of the fixed object.

Some clinical examples for cataract surgery

The clinical applications of the OQAS are numerous: they gather all clinical situations where it is important to objectivise and quantify the reduction of the optical quality of the measured eye caused by an increase of the high degree aberrations and a reduction of the transparency of the ocular environments. The crystalline lens opacities refract and diffract in a random way the incident light focused towards the retina, but the anatomo-clinic parallelism between the degree of opacity estimated with the slit lamp examination and the repercussion of these opacities on the optical quality of the eye is not always relevant, in particular for young cataracts. A permanent visual discomfort („veil") can be compatible with a moderate decrease of visual acuity. (Figure 5).

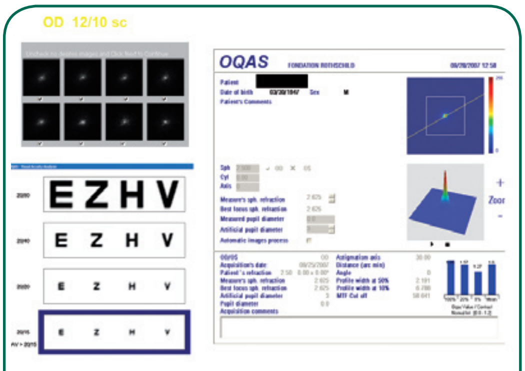

figure 5

Some instruments dedicated to the imagery of the anterior segment like the acquisition system via Scheimplflug camera make it possible to quantify the degree of

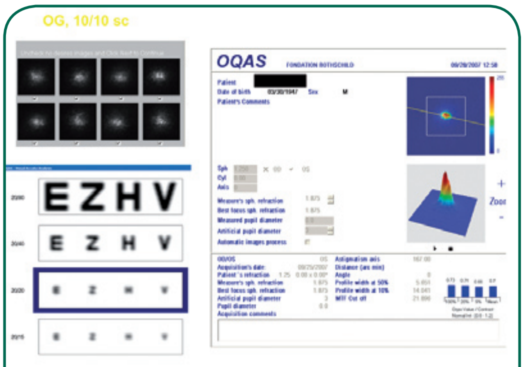

figure 5

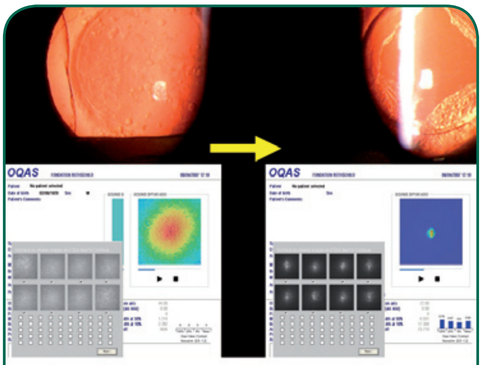

figure 6

opacification of the crystalline lens by a densitometry technique. But the effect of this light transmission opacification is not measured with this instrument.

The direct measurement of ocular light scatter is more relevant because it translates the objective effect of crystalline lens opacities on the incident light. It should enable the confirmation or not of the responsibility of a young cataract in the genesis of visual symptoms, and to establish a functional classification of the cataract from the OSI's values (Figure 3). OQAS's measurements confirm or not the responsibility of a diffuse opalescence or a discrete biomicroscopic opacities in the genesis of visual trouble. This capacity to objectivise the effect of a reduction of the crystalline lens transparency enables to forecast a possible medico-legal role in the crystalline lens surgery (objective distinction between clear crystalline lens surgery and cataract surgery). The direct visualization of the retinal PSF deterioration help to confirm the responsibility of a posterior capsular opacification in case of doubt about the diagnosis of the assessment of a visual acuity drop on a pseudophakic patient. The improvement of the PSF after capsulotomy reflects the reduction of the consecutive scatter at the capsular opening (Figure 6).

Traditional aberrometric methods (ex; Hartmann-Schack) do not enable an accurate measurement of vision quality after insertion of multifocal diffractive optics[3]. The principle of the rebuilding of the wavefront requires a monofocal optic, and cannot properly describe the variations caused by the diffractive network of the implant. The measurements of OQAS are more relevant in this context, because they are carried out from the collection of the retinal image which contains all optical information (combined effect of monofocal optics and the diffractive network) (Figure 7).

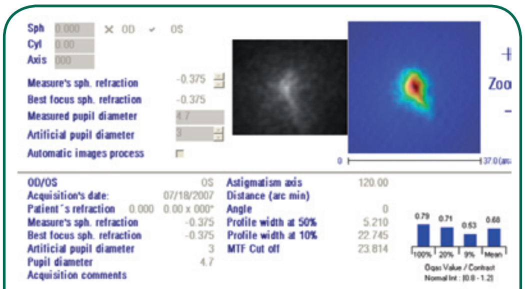

figure 7

The possibility of exploring the depth of field should make OQAS an instrument particularly adapted to objectivise the accommodative pseudo effect of the multifocal lenses and the accommodative effects of the implants known as accommodative.

Conclusion

The OQAS provides valuable information to the clinician involved in the study and treatment of pathologies responsible for the reduction of ocular transparency with cataract on top of the list. It has become essential in our daily treatment of anterior segment diseases.

References

1) Díaz-Doutón F, Benito A, Pujol J, Arjona M, Güell JL, Artal P.Comparison of the retinal image quality with a Hartmann-Shack wavefront sensor and a double-pass instrument. Invest Ophthalmol Vis Sci. 2006;47(4):1710-6.

2) In "Principles and Practice of Ophthalmology, 4rd Edition". Daniel M. Albert and Frederick A. Jakobiec, Saunders, Elsevier, USA, 2007. Gatinel D. Corneal Topography and Wavefront analysis.

3) Gatinel D. The low accuracy of Shack-Hartman wavefront sensing in eyes with diffractive multifocal intra ocular lenses. J Cataract Refract Surg, in press